No. 13.

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DESCRIPTION

OF

SIEMENS' UNIVERSAL GALVANOMETER.

So many different kinds of instruments had hitherto to be used when making electrical measurements of the intensity and electromotive force of a battery, or when finding the resistance of a conductor of either high or low resistance, that it was considered desirable to construct an instrument combining in itself the arrangements necessary for all these operations, so as to afford every facility to the telegraph engineer for making his usual experiments. With this view the Siemens' Universal Galvanometer was constructed, and it serves for the following purposes:—

1. For measuring electrical resistances;
2. For comparing electromotive forces;
3. For measuring the intensity of a current.

For measuring electrical resistances the instrument is arranged as a Wheatstone's bridge; for the comparison of electromotive forces, Professor E. du Bois-Reymond's modification of Poggendorff's compensation method is used; and to measure the intensity of a current the instrument is simply used as a sine galvanometer.

The instrument consists of a sensitive galvanometer, which can be turned in a horizontal plane, combined with a resistance bridge (the wire of which bridge instead of being straight is stretched round part of a circle). The galvanometer has an astatic needle, suspended by a cocoon fibre, and a flat bobbin frame, wound with fine wire. The needle swings above a cardboard dial divided in degrees; as, however, when using the instrument the deflection of

the needle is never read off, but the needle instead always brought to zero, two ivory limiting pins are placed at about 20 degrees on each side of zero.

The galvanometer is fixed on a graduated slate disc, round which the platinum wire is stretched. Underneath the slate disc three resistance coils of the value of 10, 100 and 1000 Siemens' Units are wound on a hollow wooden block, which protrudes at one side, and on the projection carries the terminals for the reception of the leading wires from the battery and unknown resistance. The adoption of three different resistance coils enables the measuring of large as well as small resistances with sufficient accuracy.

The whole instrument is mounted on a wooden disc, which is supported by three levelling screws, so that it may be turned round its axle. On the same axle a lever is placed which bears at its end an upright arm, carrying a contact roller. This roller is pressed against the platinum wire round the edge of the slate disc by means of a spring acting on the upright arm, and forms the junction between the A and B resistances of a Wheatstone's bridge, which resistances are formed by the platinum wire on either side of the contact roller, one of the three resistance coils forming the third resistance of the bridge.

In the accompanying drawings, fig. 1, Plate I. shows an elevation, and fig. 2, Plate I. a plan of the instrument. G is the galvanometer, k a milled head from which the needles are suspended, and by turning k they can be raised or lowered, m is the head of a screw which arrests or frees the needle when in motion. h_1, h_2, h_3, h_4, are the terminals of the respective ends of the three resistance coils, viz. 10, 100 and 1000 units which are wound on the wooden block C; these terminals may be connected to each other by means of stoppers, and therefore one or more of the resistances may be brought into circuit as desired, and to the ends of these terminals the wires of the artificial resistances are connected as shown on diagrams Plate II. figs. 1, 2, 3a and 3b; f is the graduated slate disc, round which the platinum wire is stretched in a slight groove at the edge of the disc, and is inserted in such manner that about half its diameter protrudes beyond the slate. The ends of the platinum wire are

soldered to two brass terminals l and l^1, which are placed at the angles formed by the sides of the gap in the slate disc, and which form the junctures, as in the ordinary resistance bridge, between A, n, and the galvanometer on one side, and B, X, and the galvanometer on the other side, of the parallelogram. The terminal l is permanently connected by a thick copper wire or metal strip to terminal h_1, and the other terminal l^1 is connected in a similar manner to terminal III.

Slate is adopted for the material of which to make the disc f, because it is found by experience to be the material which is the least sensitive to variations in the weather or temperature.

The slate disc is graduated on its upper edge through an arc of 300 degrees, zero being in the centre, and the graduations figured up to 150 on each side at the terminals l and l^1 of the bridge wire.

In the centre of the circular Plate E of polished wood, supported upon three levelling screws b b b, a metal boss is inserted, in which turns the vertical pin a which carries the instrument. This pin, being well fitted to the boss, supports the instrument firmly, but at the same time allows it to be turned freely round its vertical axis without losing its horizontal position when once obtained.

On the arm D D, which turns on the pin a, and somewhat behind the handle g, there is a small upright brass arm d turning between two screw points r, and carrying in a gap at its upper end a small platinum jockey pulley e turning on a vertical axis. This pulley forms the moveable contact point along the bridge wire, against which it is kept firmly pressed by means of a spring acting on the arm d. The arm D D, which is insulated from the other parts of the apparatus, is permanently connected with the terminal I. On the top of d a pointer Z or a vernier is fixed, which laps over the upper edge of the slate disc and points to the graduations.

To the pin a is attached a circular disc of polished wood C, about one inch thick, and having a groove turned in its edge for the reception of the insulated wires composing the resistances. The disc C has a projection c, which carries the five insulated terminals marked I, II, III, IV, V, as shown on figs 1 and 2, Plate I. Terminals III and IV

can be connected by a plug, II and V by the contact key K. Terminal I is in connection with the lever D D.

Figs. 3 and 4, Plate I. show the shunt box supplied with the galvanometer if specially desired; the copper connecting arms a, a are screwed to the terminals II and IV. By inserting a plug at c (fig. 4, Plate I.) the galvanometer is put out of circuit altogether, whilst by plugging either of the other holes shunts of the value of $\frac{1}{9}$, $\frac{1}{99}$ or $\frac{1}{999}$, are introduced into the circuit, and the effect upon the galvanometer is reduced to $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, respectively of what it would have been without the insertion of the shunt.

Figs. 5 and 6, Plate I. show a battery commutator allowing to bring into the circuit four different amounts of battery power. It is placed in the battery circuit whenever consecutive tests with different batteries are desired to be made, it being only necessary to change the place of the stopper in the battery commutator, the terminal screw a of the battery commutator being connected to terminal V of the galvanometer, and the screws b, b, b, b to various sections of the battery; see diagram of connections, fig. 4, Plate II.

The application of the Universal Galvanometer will be clear from the diagrams on Plate II.; instructions, however, for its practical use are added further on, and also tables for use when measuring conducting resistances.

As will be seen from diagram, fig. 1, Plate II. the proportion between the unknown resistance X, and the artificial resistance n is, when the deflection is read off on the side of the slate disc marked A:

$$X : n = 150 + a : 150 - a,$$

$$\text{or,} \quad X = \frac{150 + a}{150 - a} \cdot n;$$

but if read off on the B side of the disc—

$$X = \frac{150 - a}{150 + a} \cdot n.$$

The values of these two fractions, for every half degree, will be found in the columns headed A and B of the accompanying table.

TABLE.

Arc. α	A $\frac{150+\alpha}{150-\alpha}$	B $\frac{150-\alpha}{150+\alpha}$	Arc. α	A $\frac{150+\alpha}{150-\alpha}$	B $\frac{150-\alpha}{150+\alpha}$	Arc. α	A $\frac{150+\alpha}{150-\alpha}$	B $\frac{150-\alpha}{150+\alpha}$
145	59·00	0·017	124·5	10·76	0·093	104	5·52	0·182
144·5	53·54	0·019	124	10·54	0·095	103·5	5·45	0·183
144	49·00	0·020	123·5	10·32	0·097	103	5·38	0·186
143·5	45·15	0·022	123	10·11	0·099	102·5	5·31	0·188
143	41·86	0·024	122·5	9·91	0·101	102	5·25	0·190
142·5	39·00	0·026	122	9·72	0·103	101·5	5·18	0·193
142	36·50	0·028	121·5	9·53	0·105	101	5·12	0·195
141·5	34·29	0·029	121	9·35	0·107	100·5	5·06	0·198
141	32·33	0·031	120·5	9·17	0·109	100	5·00	0·200
140·5	30·58	0·033	120	9·00	0·111	99·5	4·94	0·202
140	29·00	0·035	119·5	8·84	0·113	99	4·88	0·205
139·5	27·57	0·036	119	8·68	0·115	98·5	4·82	0·207
139	26·27	0·038	118·5	8·52	0·117	98	4·77	0·209
138·5	25·09	0·040	118	8·37	0·119	97·5	4·71	0·212
138	24·00	0·042	117·5	8·23	0·121	97	4·66	0·215
137·5	23·00	0·044	117	8·09	0·123	96·5	4·61	0·217
137	22·08	0·045	116·5	7·96	0·126	96	4·55	0·220
136·5	21·22	0·047	116	7·82	0·128	95·5	4·50	0·222
136	20·43	0·049	115·5	7·69	0·130	95	4·45	0·224
135·5	19·69	0·051	115	7·57	0·132	94·5	4·40	0·227
135	19·00	0·052	114·5	7·45	0·134	94	4·36	0·230
134·5	18·35	0·054	114	7·33	0·136	93·5	4·31	0·232
134	17·75	0·056	113·5	7·22	0·139	93	4·26	0·235
133·5	17·18	0·058	113	7·11	0·141	92·5	4·22	0·237
133	16·65	0·060	112·5	7·00	0·143	92	4·17	0·240
132·5	16·14	0·062	112	6·89	0·145	91·5	4·13	0·242
132	15·67	0·064	111·5	6·79	0·147	91	4·08	0·245
131·5	15·22	0·066	111	6·69	0·150	90·5	4·04	0·247
131	14·79	0·068	110·5	6·59	0·152	90	4·00	0·250
130·5	14·38	0·070	110	6·50	0·154	89·5	3·96	0·253
130	14·00	0·071	109·5	6·41	0·156	89	3·92	0·255
129·5	13·63	0·073	109	6·32	0·158	88·5	3·88	0·258
129	13·28	0·075	108·5	6·23	0·160	88	3·84	0·260
128·5	12·95	0·077	108	6·14	0·163	87·5	3·80	0·263
128	12·64	0·079	107·5	6·06	0·165	87	3·76	0·266
127·5	12·33	0·081	107	5·97	0·168	86·5	3·72	0·269
127	12·04	0·083	106·5	5·89	0·170	86	3·69	0·271
126·5	11·76	0·085	106	5·82	0·172	85·5	3·65	0·274
126	11·50	0·087	105·5	5·74	0·174	85	3·62	0·276
125·5	11·24	0·089	105	5·67	0·176	84·5	3·58	0·279
125	11·00	0·091	104·5	5·59	0·179	84	3·54	0·282

TABLE—*continued.*

Arc.	A $150+\alpha$	B $150-\alpha$	Arc.	A $150+\alpha$	B $150-\alpha$	Arc.	A $150+\alpha$	B $150-\alpha$
α	$150-\alpha$	$150+\alpha$	α	$150-\alpha$	$150+\alpha$	α	$150-\alpha$	$150+\alpha$
83·5	3·51	0·285	63	2·448	0·408	42·5	1·790	0·558
83	3·48	0·288	62·5	2·428	0·412	42	1·777	0·562
82·5	3·44	0·290	62	2·409	0·415	41·5	1·765	0·567
82	3·41	0·293	61·5	2·389	0·418	41	1·752	0·571
81·5	3·38	0·296	61	2·370	0·422	40·5	1·739	0·575
81	3·35	0·299	60·5	2·352	0·425	40	1·727	0·579
80·5	3·31	0·302	60	2·333	0·429	39·5	1·714	0·583
80	3·28	0·304	59·5	2·315	0·432	39	1·702	0·587
79·5	3·25	0·307	59	2·296	0·435	38·5	1·690	9·592
79	3·22	0·310	58·5	2·278	0·439	38	1·679	0·596
78·5	3·19	0·313	58	2·261	0·442	37·5	1·667	0·600
78	3·17	0·316	57·5	2·243	0·446	37	1·655	0·604
77·5	3·14	0·319	57	2·226	0·449	36·5	1·643	0·609
77	3·11	0·322	56·5	2·208	0·453	36	1·631	0·613
76·5	3·08	0·325	56	2·191	0·456	35·5	1·620	0·617
76	3·05	0·327	55·5	2·174	0·460	35	1·608	0·622
75·5	3·03	0·330	55	2·158	0·463	34·5	1·597	0·626
75	3·00	0·333	54·5	2·141	0·467	34	1·586	0·630
74·5	2·973	0·336	54	2·125	0·471	33·5	1·575	0·635
74	2·947	0·339	53·5	2·109	0·474	33	1·564	0·639
73·5	2·921	0·342	53	2·093	0·478	32·5	1·553	0·644
73	2·896	0·345	52·5	2·077	0·481	32	1·542	0·648
72·5	2·871	0·348	52	2·061	0·485	31·5	1·531	0·653
72	2·846	0·351	51·5	2·045	0·489	31	1·521	0·657
71·5	2·822	0·354	51	2·030	0·492	30·5	1·510	0·662
71	2·797	0·357	50·5	2·015	0·496	30	1·500	0·667
70·5	2·773	0·360	50	2·000	0·500	29·5	1·489	0·671
70	2·750	0·364	49·5	1·985	0·504	29	1·479	0·676
69·5	2·726	0·367	49	1·970	0·508	28·5	1·469	0·681
69	2·703	0·370	48·5	1·955	0·511	28	1·459	0·685
68·5	2·680	0·373	48	1·941	0·515	27·5	1·449	0·690
68	2·658	0·376	47·5	1·926	0·519	27	1·439	0·695
67·5	2·636	0·379	47	1·913	0·523	26·5	1·429	0·700
67	2·614	0·382	46·5	1·898	0·527	26	1·419	0·705
66·5	2·592	0·386	46	1·884	0·531	25·5	1·409	0·709
66	2·571	0·389	45·5	1·870	0·535	25	1·400	0·714
65·5	2·550	0·392	45	1·857	0·538	24·5	1·390	0·719
65	2·529	0·395	44·5	1·843	0·542	24	1·380	0·724
64·5	2·509	0·398	44	1·830	0·546	23·5	1·371	0·729
64	2·488	0·402	43·5	1·816	0·550	23	1·362	0·734
63·5	2·468	0·405	43	1·803	0·554	22·5	1·352	0·739

TABLE—*continued.*

Arc.	A $150+\alpha$	B $150-\alpha$	Arc.	A $150+\alpha$	B $150-\alpha$	Arc.	A $150+\alpha$	B $150-\alpha$
α	$150-\alpha$	$150+\alpha$	α	$150-\alpha$	$150+\alpha$	α	$150-\alpha$	$150+\alpha$
22	1·343	0·744	14·5	1·214	0·823	7	1·097	0·911
21·5	1·334	0·749	14	1·206	0·829	6·5	1·090	0·917
21	1·325	0·754	13·5	1·198	0·835	6	1·083	0·923
20·5	1·316	0·760	13	1·189	0·841	5·5	1·076	0·929
20	1·307	0·765	12·5	1·181	0·847	5	1·068	0·935
19·5	1·298	0·770	12	1·173	0·852	4·5	1·061	0·942
19	1·290	0·775	11·5	1·166	0·858	4	1·054	0·948
18·5	1·281	0·780	11	1·158	0·863	3·5	1·047	0·954
18	1·272	0·786	10·5	1·150	0·869	3	1·040	0·960
17·5	1·264	0·791	10	1·143	0·875	2·5	1·033	0·967
17	1·255	0·796	9·5	1·135	0·881	2	1·027	0·974
16·5	1·247	0·802	9	1·127	0·887	1·5	1·020	0·980
16	1·238	0·807	8·5	1·120	0·893	1	1·013	0·987
15·5	1·230	0·813	8	1·112	0·899	0·5	1·006	0·993
15	1·222	0·818	7·5	1·105	0·905			

Instructions for the use of Siemens' "Universal Galvanometer."

This instrument can be used for the following purposes:—

FIRSTLY. For finding an unknown resistance X, see figs. 1 and 5, Plate II.

(*a*) The needle *i* is to be brought to the zero point of the small cardboard scale by turning the galvanometer G round its vertical axis, taking care that the needle moves with perfect freedom;

(*b*) The pointer or vernier Z is to be brought, by means of the handle *g*, to the zero point of the large scale on the slate disc;

(*c*) A plug is to be inserted between the terminals marked III and IV;

(*d*) The holes 10, 100 and 1000 are, two of them, to be plugged and one left open according to the extent of the

unknown resistance to be measured; either 10 or 100 must be left open if the resistance is small, and 1000 if it is large;

(*e*) The two ends of the unknown resistance are to be connected to terminals II and IV;

(*f*) The two poles of some galvanic battery are to be connected to terminals I and V;

When the above-mentioned connections have been made, and on depressing the key K, the battery-current is sent into the combination and deflects the needle, say, to the right hand or B side of the instrument, the pointer or vernier Z must then be pushed, by means of the handle *g*, to the B side of the instrument. If this is found to increase the deflection of the needle *i*, the pointer Z should be pushed to the other or A side of the instrument beyond the zero point of the large scale until the needle remains stationary when the key K is depressed.

The number indicated by the vernier Z should be read off carefully, and notice taken whether it is on the A or B side of the large scale. This number must then be referred to the accompanying Table, when the figure opposite to the number, multiplied by the resistance unplugged, is the resistance of X. The value of the resistance to be determined will be thus found by a single operation.

Supposing the reading to be 50° on the A side of the large scale, the resistance *n* unplugged having been 100 units, we get according to the before-mentioned law of resistance-bridge the following proportion (see fig. 5, Plate II.):—

$$X : 100 = 150 + 50 : 150 - 50$$

$$X = \frac{150 + 50}{150 - 50} \cdot 100$$

$$X = 200 \text{ units.}$$

For measuring very small resistances a single cell will be found sufficient; but for large resistances more should be used, say, 15 to 20. If very accurate measurements of small resistances are to be taken, the screw at the end of the moving arm DD should receive one battery-wire, terminal V receiving the other.

SECONDLY. For comparing two electromotive forces E_1 and E_2, a third electromotor of higher electromotive force E_0 is used, and two separate tests taken. (See figs. 2 and 6, Plate II.)

The manipulations (*a*) and (*b*) are to be the same as before.

(*c*) The hole between III and IV to be left unplugged.

(*d*) Plugs to be inserted in 10, 100 and 1000.

(*e*) The two poles of the electromotor of an electromotive force E_0 are to be connected to the terminals III and V.

(*f*) The poles of the battery whose electromotive force E_1 is to be compared are connected to terminals I and IV in such a manner that the similar poles of the two electromotors are joined to terminals I and III and to IV and V respectively.

When depressing the key K the galvanometer needle will be deflected and can be brought back to zero by turning the pointer Z either to the right or the left. Should for instance the pointer have to be brought to 30° on the A side we have the following equation—

$$E_1 = E_0 \frac{150 - 30}{300 + n} \ldots\ldots\ldots (1),$$

where n is the resistance of the battery E_0.

The electromotor E_2 is now to be inserted in the place of E_1, and the galvanometor needle, when it deflects, again brought back to zero by moving the pointer Z. If for instance the pointer has to be pushed to 40° on the B side to obtain equilibrium we have—

$$E_2 = E_0 \frac{150 + 40}{300 + n} \ldots\ldots\ldots\ldots (2).$$

By eliminating n from equations 1 and 2 we have

$$E_1 : E_2 = (150 - 30) : (150 + 40) = 12 : 19 \ldots\ldots (3).$$

The two electromotive forces are in the same proportion as the two observed distances of the pointer Z from 150° on the A side of the instrument.

THIRDLY. As a sine galvanometer.

(See figs. 3 *a* and 7.)

The manipulations *a*, *b*, *c* and *d*, same as in the second case.

(*e*) Connect one pole of a battery to terminal II. and put the other pole to earth.

(*f*) Connect the line to terminal IV.

The galvanometer is then to be turned in the same direction as the needle is deflected until the needle coincides with the zero point. Whilst this is being done the large scale on the slate disc will move under the pointer Z, which must be left stationary; the sine of the angle indicated by Z will thus give the value proportionate to the strength of the current. Should the shunt box be required, it has to be connected with terminals II. and IV.

Fig. 4 shows the same connections as fig. 7, but without the shunt-box, and with the battery commutator. Fig. 3^a shows diagram of the same connections but with the key K, and fig. 3^b the same without the key.

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SIEMENS' UNIVERSAL GALVANOMETER.

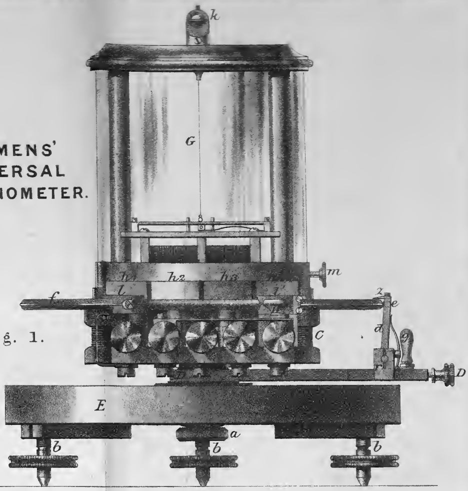


Fig. 1.

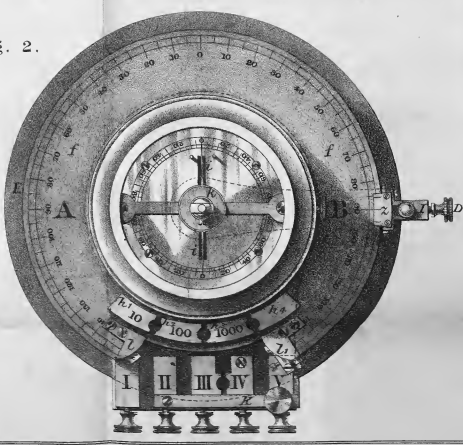


Fig. 2.

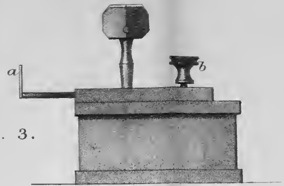


Fig. 3.

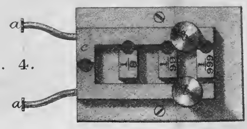


Fig. 4.

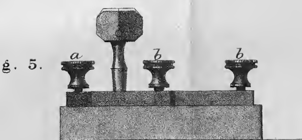


Fig. 5.

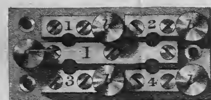


Fig. 6.

WHEN MEASURING RESISTANCES.

AS SINE GALVANOMETER.

Fig. 1.

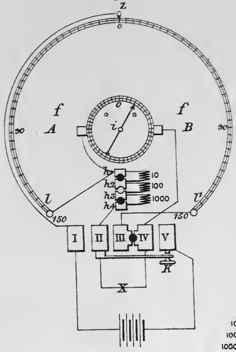


Fig. 3 *a*

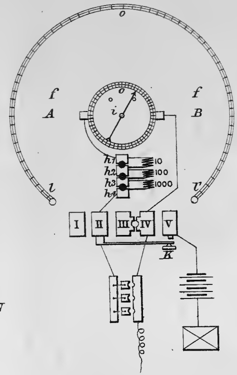


Fig. 3 *b*

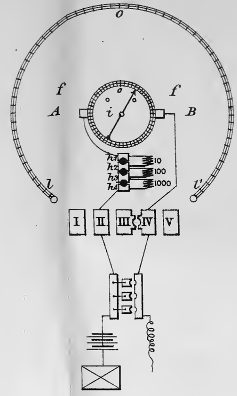


Fig. 5.

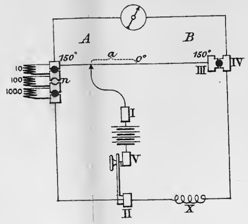


Fig. 7.

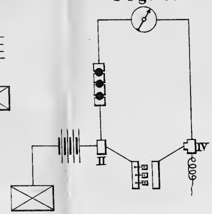


Fig. 2.

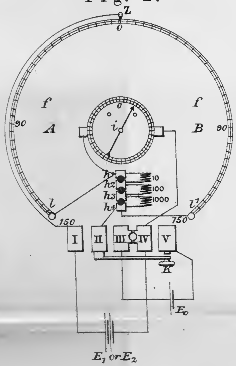


Fig. 6.

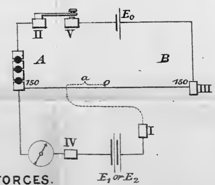
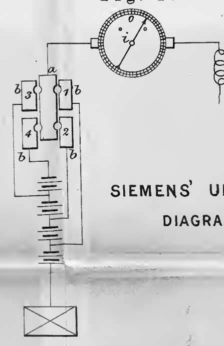


Fig. 4.



SIEMENS' UNIVERSAL GALVANOMETER

DIAGRAMS OF CONNECTIONS.

WHEN COMPARING ELECTROMOTIVE FORCES.

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